NEW ENGLAND WATER WORKS ASSOCIATION.
ORGANIZED 1882.

Vol. III. Dec. 1888. No. 2.

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QUARTERLY MEETING.

A FIELD DAY AT CAMBRIDGE, MASS., SEPTEMBER 12, 1888.

Over one hundred members and guests assembled at Union Hall, Cambridge, where, after a ride to Fresh Pond and Stony Brook dam, and an inspection of the works at these places, the entire company sat down to a banquet tendered by the Cambridge City Government and Water Board. The banquet was presided over by Mayor William Russell, who called upon various members and guests to respond to the toasts offered.

The following paper is republished from the Journal of the Association of Engineering Societies, it having been read before the Boston Society of Civil Engineers. The paper is substantially the same as the one read before this Association at the annual convention in June, 1888, of which the copy was mislaid.

THE METHODS AND APPARATUS USED IN THE RECENT TEST OF WATER METERS AT BOSTON.

BY

L. FREDERICK RICE, CIVIL ENGINEER, BOSTON, MASS.

In March, 1887, L. Frederick Rice, Civil Engineer, Charles Carr, Mechanical Engineer, and Nathaniel M. Lowe, Mechanical Expert, were requested by the Boston Water Board to undertake, in its behalf, the examination of such water meters as might be designated, "making a full test and report upon their merits."

The Water Board gave no instructions as to methods of procedure, and imposed no restrictions whatever; assuming only that the scheme of work would be carefully considered before adoption, and asking that such scheme, when determined upon, should be submitted to the board for its approval. The desire was expressed that the examination of meters should be "so far public as to leave no room for question."

In compliance with this desire, the work of the Testing Commission has been done in a room open to whoever chose to visit it for the purpose of witnessing the operations. Fortunate in securing skillful assistants, the Commission has been able to dispense with the volunteer aid so kindly proffered at an early stage of its labors.

In the belief that a description of the work done and the methods and apparatus used in these experiments may be of interest to members of this Society and possibly to others, this paper has been prepared.

Before deciding upon the course of action to be adopted in making the desired tests, the Commission carefully considered the functions of a water meter,—the forces by which it is actuated,—the circumstances under which it acts and the various causes modifying its action.

A water meter is an instrument used for measuring water as it passes through a pipe, and recording the quantity measured in such manner as to form the basis of charges for the use of the water.

The *perfect* meter will make an absolutely accurate *measurement*, uninfluenced by variations of pressure, or rate of flow,—guiltless of leakage and undeterred by frictional or other resistance,—and it will honestly and truly *register* and declare the exact amount of such measurement, regardless of remissness or only partial performance of duty on the part of the measuring apparatus.

It will continue to do this for an indefinite period,—in gritty as well as in clear water,—with the temperature of the air or water below 32° or above 212° Fahr., or at any intermediate point,—located in the attic or in the coal bin,—set level or plumb or in any other position that carelessness or ignorance or malice can devise; and although busy and scheming brains work tirelessly over the problem of how to "beat the meter," it will never be caught napping nor fail in its duty.

We have it from good authority that the perfect meter has not yet been found."

It might, perhaps, be classed with the philosopher's stone and perpetual motion; tantalizing, but unattainable.

But why seek a standard of measure of greater value than the commodity dealt in? Why should time and money be expended in the search for absolute accuracy in measuring *water*, whose value in this market, sold by meter, is two cents per 100 gallons or 15 cents per 100 cubic feet,—equal to $1.50 per 1,000 cubic feet, or $45 per 30,000 cubic feet, which is an average yearly duty for a ¾-inch meter in this city.

Forty-five dollars per year is 12½ cents per day for 617 gallons, or one cent apiece for every person who uses 50 gallons of water daily. If the meter by which this water is to be measured should vary 5 per cent. from perfect accuracy, what would be the yearly cost of the error? $2¼! Fifty-six cents in the quarterly bill.

The Testing Commission endeavored to ascertain wherein the various meters submitted to it failed of perfection, and the degree of such failure; also if

such failure was the result of faults of design, or of workmanship, or of material; and also whether any means could be discovered whereby the action of any meter could be improved.

Water is usually distributed through cities and towns by means of a system of pipes, through which it is forced by pumps, or flows by gravitation from some source more or less elevated. If the water in any pipe system is at rest, a gauge applied at any point thereof, would indicate the weight of a column of water whose height equalled the difference in elevation between the gauge and the supply reservoir; or the pressure maintained by the pump. This is designated the "static pressure or head."

If, by drafts upon a pipe system, a movement of the water therein is caused, the velocity of such movement creates certain resistances, by reason of friction of the water upon the interior surface of the pipes, or the obstruction afforded by abrupt changes of direction or of size. In overcoming these resistances, a portion of the static pressure is expended, and water would be delivered upon the premises of a consumer at an effective pressure, which would be the *static pressure* reduced by the sum of such *resistances*, and by the actual withdrawal of a portion of the water for the supply of other consumers. *This* may be considered as the initial pressure for any consumer, *not* what is due to the height of the reservoir or pressure at the pump which furnishes the supply.

The usual practice is for individual water takers to bring water from the street main into their premises through a small pipe. In the majority of instances the inlet or supply pipe for dwelling houses is $\frac{5}{8}$ inch or $\frac{3}{4}$ inch in diameter, and varies in length from perhaps 20 feet to 100 feet, or even more.

At the end of the supply pipe the meter is placed, usually in the cellar or basement of a building, where it will be more or less protected from frost. But when the water is passing through the meter, the velocity of flow through the *supply* pipe creates resistances *therein*, by which the pressure under which the meter operates (as would be indicated by a gauge placed close to its inlet), is not that due to the *elevation of the reservoir*, nor yet the *effective pressure in the main* in front of the premises, but the latter, *reduced* by the resistances encountered in the *supply pipe*.

If the moving parts of a meter are closely fitted, the accuracy of fit causes a resistance to motion—a true friction.

When a valve of a meter is under a heavy pressure its movement develops friction by which resistance is offered to the motion of the piston. If the water passages in a meter are long, or crooked, or of small diameter, or constricted at certain points, or if the ports are small, all these offer resistances to the passage of water through the *meter*. All these meter resistances serve to consume a portion of the pressure at the *inlet* of the meter.

From the outlet of the meter, the house distributing pipe, usually of $\frac{3}{4}$-inch, 1-inch, $1\frac{1}{4}$-inch and $1\frac{1}{2}$-inch diameter, conveys the water by routes more or less tortuous, to convenient points throughout the house, and it is drawn therefrom through faucets which are situated at various heights above the meter, and which may be opened partially or to their full capacity, as may be desired.

We thus encounter additional resistance in the distributing pipes, and a part of the pressure remaining at the *outlet* of the meter is taken up in overcoming them.

When water finally reaches the faucet, the volume or discharge varies with the amount that the faucet is opened, which is, of course, at the consumer's option.

Or, expressed more concisely, the *initial pressure* at the entrance to the premises of any consumer is reduced by certain resistances met with in the *inlet pipe*, caused by friction upon the interior surface thereof (dependent upon its diameter and length), —changes of direction (dependent upon the number of such changes and their degree and abruptness), —and changes of size, (dependent upon their number and degree).

The initial pressure is further reduced by the resistance offered by the *meter* (dependent upon the intricacy and size of the water passages, and the friction of its moving parts.)

The initial pressure is still further reduced by the resistances encountered in the *outlet pipe* (dependent upon its size, length, changes of direction and size, etc., and also upon the elevation of the orifice of discharge above the meter).

The quantity of water *obtainable by the consumer* is that which the *effective pressure* (or what is left of the initial pressure after the various reductions above enumerated) *can force through the orifice of discharge*, and *this* is finally modified by the size and conformation of that orifice, or by the variety of faucet employed and its degree of opening.

Hence it is of vital importance to a *consumer* of water that his piping, meter and fixtures shall be so designed and constructed that the sum of these reductions shall be a minimum.

If the moving parts of a meter fit loosely, there will be more or less leakage of water by the piston or through the valves without communicating motion to the measuring members, and consequently without registration, or with a registration in favor of the consumer.

It is therefore of importance to *water boards*, or any *persons who have water to sell*, that the leakage without registration should be a minimum.

It is of importance to *both buyer and seller* that the details of the action of a meter under any and all circumstances and conditions, shall be *known quantities* and not mere assumptions.

Influenced by the foregoing considerations, the Testing Commission determined to reproduce, as far as possible, the conditions of actual practice, and to test each meter under various initial pressures, combined with such resistances to a free discharge of water as are liable to be encountered, —to note carefully all the data of each experiment and keep a full record of all the results obtained and phenomena observed, —and to make such notes and record a part of the report, in order that the conclusions of the Commission might be verified or disproved by any interested parties.

It was decided that after the accuracy of each meter had been tested, it should be subjected to a trial to determine the effect of continued usage upon the accuracy and also the durability of the meter, —and that examination should finally be made of the interior, to determine its condition and to

enable a study to be made of the nature and quality of the materials used in the construction,—the workmanship,—the design, both in general and in detail,—the cost, both of maintenance and originally,—the space occupied,—the weight, and the facilities for adjustment and repairing; in short to try every meter under all practicable conditions, and make such examination and study as would disclose the cause of, and if possible the remedy for, any erratic action that might be indicated by the record, and show whether an apparent defect was capable of correction or removal either by the use of different material, better workmanship or change of proportions of parts,—or if it was due to the inherent fault or inadequacy of the design of the meter.

Later it was decided to supplement the records and report based thereon, by appending photographs showing the external appearance of each meter tested, and also such portions of the interiors as should seem desirable to exhibit the effects of the experiments.

The meters placed in the hands of the Commission for testing were mostly of 1-inch and ¾-inch capacity. In a few instances, where none of the smaller size could be obtained, samples of ⅝-inch capacity were substituted. The Commission decided to fully try the ¾ and ⅝-inch meters of all the various kinds submitted, before passing to the larger size. Subsequently, in view of the lapse of time occasioned by the multiplicity of meters to be tested, all trial of the 1-inch meters was omitted. Still it is believed that the experiments made were sufficiently extended, and the study of the construction and action of the various meters sufficiently comprehensive to justify conclusions applicable not only to the particular samples tested. but to the *types* of meters to which the samples belong.

THE TESTING APPARATUS

was devised by the Commission, and was erected in a room constructed in the southerly end of the basement of the Massachusetts Charitable Mechanic Association Building.

The testing room was about 65 feet long by 24 feet wide, lighted by windows on one side, and having a door at one end, secured by a lock to which only the members of the Testing Commission had keys.

Adjoining the testing-room, and accessible by a passage through it, was a small room, about 12 by 13 feet, used by the Commission as an office, and for the storage of records of the tests, and of meters while not undergoing examination.

During the entire period occupied by the tests and the preparation of the report, no person whatever had access to the testing room, or to any of the meters or testing apparatus, except in the presence of one or more members of the Testing Commission; and none but members or employes of the Commission had any connection with the operation of testing or access to the records thereof.

The testing room was divided lengthwise by a railing into two equal parts. The testing apparatus was erected in the inner one, and the outer one opened to the public at all times when testing was in progress,—the rail preventing

unauthorized access to the meters, or the apparatus, or the records, while enabling visitors to see and hear all of the operations of the tests.

Watchmen were employed, both by day and by night, to see that the premises occupied were not intruded upon,—the watchman's station being outside the testing room, but provided with facilities for observing the entire interior.

A 6-inch cast-iron pipe was laid from the large water-main in the street to the testing-room. This was controlled by a gate at each end, and in the experiments herein described served in place of the street main in actual practice.

To this, within the testing-room, was attached a ¾-inch lead pipe, about 50 feet long, laid horizontally and controlled by a gate at its junction with the larger pipe.

Another pipe of 1 inch diameter was provided for use when testing meters of that size. It proved useful in experiments where the rate of flow was so slight that the resistance from friction was inappreciable, and could, therefore, be ignored.

The apparatus, therefore, allowed the simultaneous trial of two meters.

The 1-inch and ¾-inch pipes took the place of the *service* pipes in practice, and to the inner end of either was attached the meter under trial, controlled by gates close to inlet and outlet. The outlet of the meter was connected with several vertical pipes of various lengths, but each governed by a gate at its lower end, so as to be manipulated from the testing room. These pipes, of ¾-inch diameter, represented the *distributing pipes* in an ordinary building, and, by means of the gates, water could be discharged at various heights above the meter; while, by the attachment of disks, with orifices of various sizes, to the upper ends of the pipes, the size of the stream discharged was at the option of the experimenter.

The sizes of the orifices used in these experiments were ¾, ½, ¼, .15, .05, .04, .03 and .02 inch.

In this manner it was easy to observe the effect produced upon a meter by drawing water from faucets located in the several stories of a building; the amount of opening of the faucet being under the control of the operator, who could thus cause water to be discharged at points 7½, 22, 36 and 51 feet above, or at the level of the meter.

The water thus discharged, falling into a funnel-shaped receiver, was conveyed by a pipe back to the testing room, into a tank mounted on a Howe platform scale, where its amount was determined *by weight*. When filled, the tank could be emptied into a drain pipe directly connected with the street sewer.

In order to observe the effect of light initial pressures upon the performance of the meters, as in the case of a building located at an elevation but slightly less than that of the reservoir from which the supply comes, or where the supply is nearly exhausted by other consumers before reaching the one under consideration, tanks were located over the testing-room at elevations of 7, 26, 40, 54 and 84 feet above the meter, with suitable connecting pipes, thus enabling meters to be tried under pressure of the water from either of these tanks in the manner already described.

The pipes from these tanks to the meters were one inch in diameter.

Gauges were placed at the end of the 6-inch pipe, and at the inlet and outlet to the meter.

Plate 1 shows the general arrangement of the testing apparatus as before described, and is self-explanatory.

It will be seen that with eight sizes of discharged orifice, and each of these tried at each of five elevations, the apparatus permits the observance of the performance of a meter under forty different conditions; and if all six sources of initial pressure be used, one hundred and eighty-four varieties of conditions may be obtained.

Identical results would doubtless be obtained in many instances, and as the record of these, especially if made in the case of 35 meters, would be very bulky, and the time consumed in the experiments very great, it was decided to omit a portion, and the report gives the record of but forty-one varieties of condition.

TEST FOR ACCURACY.

In testing the accuracy of a meter, water was passed through it until a predetermined number of cubic feet had flowed into the measuring tank. The flow was then stopped by closing the gate at the outlet of the meter, and the amount as indicated by the register of the meter compared with that actually received into the tank.

The variation between these is the "error" of the meter.

The register may indicate the passage of *more* water than is received into the tank; in which case the meter is said to "over register," or to register "against the consumer." For convenience, in the records of these trials, over-registration is indicated by the sign +.

When the register indicates the passage of *less* water than the measurement shows, the meter "under registers," or "registers in favor of the consumer," and in such cases the sign—is used in the records.

The "error" is given as a percentage of the *actual* flow.

The quantity of water received into the measuring tank being determined by weighing, it is evident that failure to shut off the water exactly simultaneously with the rising of the scale beam, would give an erroneous result, and that such failure would be very liable to occur if the shutting off be done by hand.

It was therefore decided to use an

ELECTRIC AUTOMATIC SHUT-OFF.

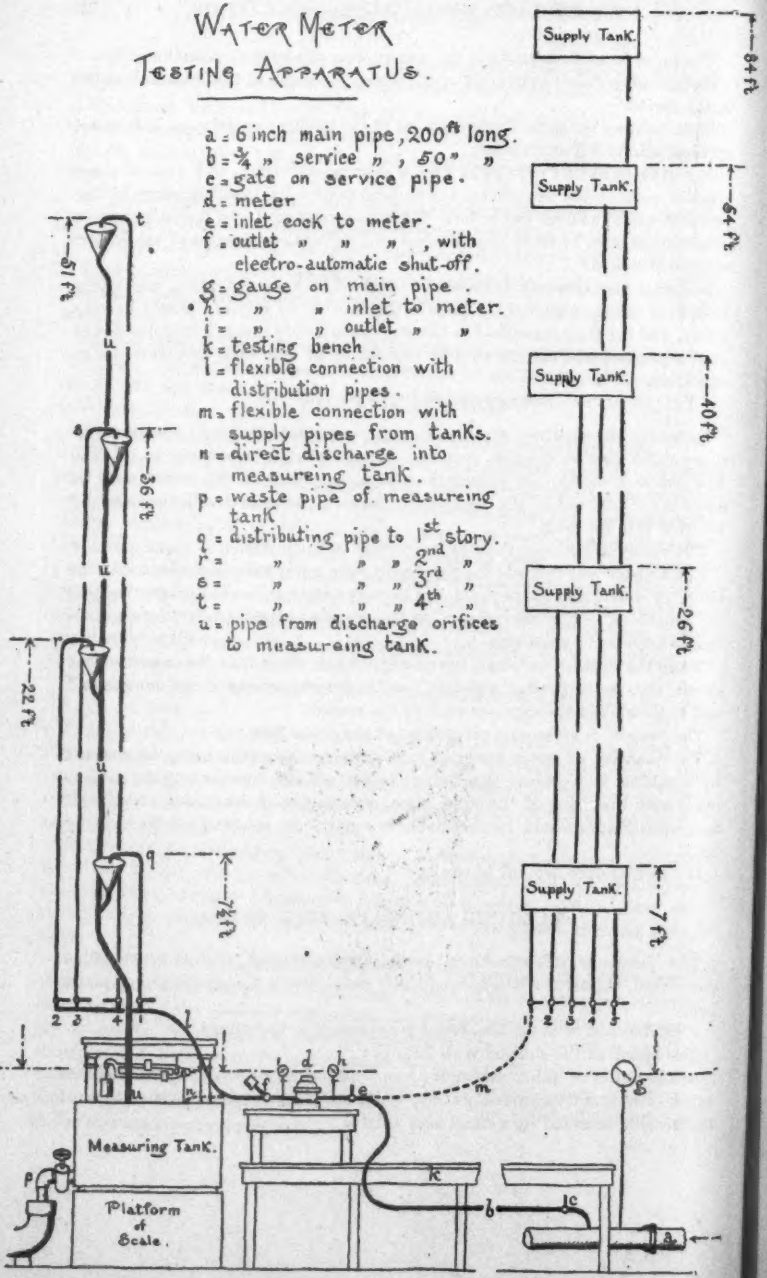
The details of this attachment having been perfected, and its construction completed, connection was subsequently made with a stop-clock and an alarm bell.

A photograph of the entire device is appended to the report.

The action of the shut-off is as follows:

At the outlet of the meter under trial is placed a full-way Chapman balance valve, of new and improved pattern, which fully closes with a quarter turn of the handle, actuated by a small lead weight.

WATER METER TESTING APPARATUS.


a = 6 inch main pipe, 200 ft long.
b = ¾ " service " , 50 " "
c = gate on service pipe.
d = meter
e = inlet cock to meter.
f = outlet " " " , with electro-automatic shut-off.
g = gauge on main pipe.
h = " " inlet to meter.
i = " " outlet " "
k = testing bench.
l = flexible connection with distribution pipes.
m = flexible connection with supply pipes from tanks.
n = direct discharge into measureing tank.
p = waste pipe of measureing tank
q = distributing pipe to 1st story.
r = " " " 2nd "
s = " " " 3rd "
t = " " " 4th "
u = pipe from discharge orifices to measureing tank.
Supply Tank.
Supply Tank.
Supply Tank.
Supply Tank.
Supply Tank.
84 ft
64 ft
40 ft
26 ft
7 ft
51 ft
36 ft
22 ft
Measuring Tank.
Platform of Scale.

When in operation the handle is held down by a detent, connected with the armature of an electro-magnet, the wires from which, passing to the platform scale on which is the measuring tank for the reception of the water from the meter, from a closed circuit.

Upon the reception into the tank of the predetermined quantity of water, the scale beam rises, breaking the circuit, --the handle of the valve is released and the valve instantaneously closed by the falling weight. Simultaneously, the clock, previously set at zero, and which has been put in motion by the opening of the valve, is stopped,—while the bell calls the attendants to note the duration of the experiment, read the register of the meter and the gauges. and perform any other duties that may be required.

In thus determining the quantity of water by weighing, it was assumed that one cubic foot of water weighed 62½ pounds, and that the scale beam, being weighted for 625 pounds, would indicate when 10 cubic feet had been received into the tank.

This assumption is not absolutely correct, since the weight of a cubic foot of water varies with the temperature, which was therefore observed and recorded, and a correction made when the "error" was calculated.

The temperature of the water during the tests varied from 46 degrees to 76 degrees Fahrenheit, corresponding to a variation in the weight of 10 cubic feet of water of from 622.2 lbs. to 623.75 lbs., and the number of cubic feet, as indicated by the scale, was therefore corrected by multiplying by a factor which varied from 1.002 to 1.0045.

This automatic shut-off proved to be of great value in facilitating the work of testing, since it entirely eliminated the possibility of error by reason of imperfect manipulation of the shut off or hurried reading or comparison of watches.

When trying a meter under a very slow delivery of water, requiring considerable time for a single experiment, the apparatus could be set in operation at the close of a day's work, and then locked up and left to do its duty unattended during the night and tell the whole story in the morning.

When trying a meter under back pressure, or when discharging from an orifice at some elevation above the meter, the pipe to the orifice was filled with water before adjusting the scale, and on the completion of the run, when the tank, having received the weight of water for which it was adjusted, stopped further flow through the meter, the water then remaining in the return pipe was allowed to run into the tank and weighed, and its weight added to that at which the scale had been set.

RECORD OF ACCURACY TESTS. (See Plate 2.)

In the record, as appended to and forming a portion of the report, the following data are given :

The name and number of the meter experimented on.

The source and elevation of the supply of water.

The date of each experiment.

The gauge-reading on main pipe.

The gauge-reading of inlet to meter (working).

The gauge-reading at outlet to meter (working).

The gauge-reading at outlet to meter (at rest).

The difference between the first and second of these gauge-readings represents the frictional resistance of the inlet or service pipe, between the main and the meter.

The difference between the second and third gauge-readings shows the resistance or loss of head due to the meter under trial.

The difference between the third and fourth gauge-readings shows the resistance offered by the house distribution-pipe and discharging-faucet.

The height of outlet above the meter is given, and corresponds to the fourth gauge-reading.

The diameters of the inlet-pipe, outlet-pipe and orifice of discharge are also recorded.

Record is then made of the duration of the trial, showing the hours, minutes and seconds occupied by each run made, and the aggregate—the latter expressed (for convenience of calculation) in minutes and decimals thereof.

Meter readings, at the beginning and end of each run, and cubic feet of flow indicated for each.

Temperature of the water.

Tank measure (in cubic feet) as indicated by the scale, the same corrected for temperature.

Ratio between the meter-reading and the corrected tank measure, from which is deduced the percentage of error of meter, + or —, or over-registration or under-registration.

From the corrected tank-measure and duration of trial are deduced the actual time needed to pass 10 cubic feet;

Actual flow per minute, in cubic feet;

Percentage of increase of time due to use of meter as compared with a pipe without meter, and percentage of decrease of delivery due to use of meter, showing the amount of reduction of capacity.

The last two items are not recorded unless exceeding 5 per cent.

Upon these record sheets are also noted all details of experiments, such as stoppages, breakages, repairs, repetitions, etc.

TEST FOR DURABILITY.

The object of this test was to determine the effect of continued use upon the accuracy of meters, as ascertainnd in the series of trials just described, and designated the first test for accuracy.

The 6 inch main, supplying the water for the experiments, was continued into the testing-room 50 feet beyond the point where the supply-pipes for the trial of single meters branched off.

This main was tapped and 24 one-inch lead branch pipes, spaced at equal distances over the entire length, inserted. Each of these branches was controlled by a stop cock. A long bench was erected over the main pipe, and a

drain pipe, with branch openings opposite the stop cocks, laid beside the main, under the bench ; and at the farther end of the testing room, near the measuring tanks, joined the main drain from thence to the street sewer.

This admitted of a number of meters being placed upon the bench, each connected with a 1-inch supply pipe, and each discharging through a separate 1-inch lead waste pipe with stop cock, into the drain.

All the meters that had passed through the first accuracy test—24 in number—were placed upon the bench and run simultaneously and continuously until their respective registers indicated that about 75,000 cubic feet of water had passed through each. This quantity is equal to about two years's average duty of meters of ¾-inch capacity, as shown by the records of the Boston Water Board.

It having been questioned whether the meters located at different points along the main would be subject to the same pressure of water, calculations were made to determine the difference of pressure. if any, between the two extremities and intermediate points. These calculations indicated that the discharge of 99.3 cubic feet of water per minute, which was the rate when all the meters were running, would cause such a velocity of flow in the 6-inch pipe from the street main to the location of the first meter, as would develop a friction considerably reducing the initial or static pressure,—but that the further reduction between the first and last meters would be but 4-10 pound, showing that there was no practical difference in the pressures upon the different meters.

To ascertain if observation confirmed the calculation, gauges were placed at each end and in the middle of the bench. These being read, water was then turned on to the first meter, and the gauges again read. The remaining meters were then successfully set in motion until all were running ; the gauges being read as each was added. The last meter was then shut off, and then the others, successively, until all were again quiescent ; still reading the gauges in the same manner. At no time was there any perceptible difference between the three gauges, but the pressure indicated by each steadily diminished as the meters were successively set in motion, and rose again as they were turned off, until on the completion of the experiment the initial pressure of 46 pounds was reached ; completely confirming the calculations, and showing that the various meters were tried under precisely similar conditions.

The previous trials showed a marked difference in the resistance to flow offered by the various meters, and also in the volume of the discharge in a given time. Those offering the least resistance were the first to reach the conclusion of this trial. As soon as any meter showed by its register that the 75,000 cubic feet of water had passed through it, it was stopped by closing its waste-cock, but the pressure was left upon the meters until all had completed the trial. The time required to pass the 75,000 cubic feet varied from nine to eighteen days.

Ten days after thus shutting off each meter, trial was made to ascertain its relative liability to obstruction by reason of sediment within the meters or by corrosion, or adhesion of parts, or from any other cause, during the period of

rest. The waste cock was opened very gradually and without shock, and note made of the degree of opening before water flowed,—the rate of flow before movement of register began,—and the variation from accuracy after starting of register.

The record of the durability trial shows the register reading of each meter three times each day,—the time of completion of trial, or failure, with cause thereof,—and notes of any occurrence of interest, peculiarities or cessation of action, etc., and the causes of same if ascertained.

SECOND TEST FOR ACCURACY.

This trial was made to ascertain the effect of continued usage upon the accuracy of a meter, and was made in a similar manner, and with the same apparatus as the first test, but under a smaller variety of conditions.

The record sheets are in a similar form.

By comparison of the records of the two tests of accuracy, the effect of the wear of the test of durability becomes apparent.

To facilitate such comparison, sheets have been prepared, on which is given a Graphic Representation of Meter Error under all the various conditions of the two tests for accuracy. These show, at a glance, for each meter and each experiment therewith, both before and after the test for durability, the actual delivery of water (as measured in a tank), and the percentage of Error of Registration, either over or under; also the maximum and minimum percentage of error; also their mean and the range between them; the average percentage of error, and the effect of wear upon the range and the average; also the general retarding effect of each meter as compared with a pipe without meter. Plate 3 is a sample sheet of the Graphical Representation of Meter Error, compiled from Plate 2 and other record sheets.

A CONSOLIDATED REPORT

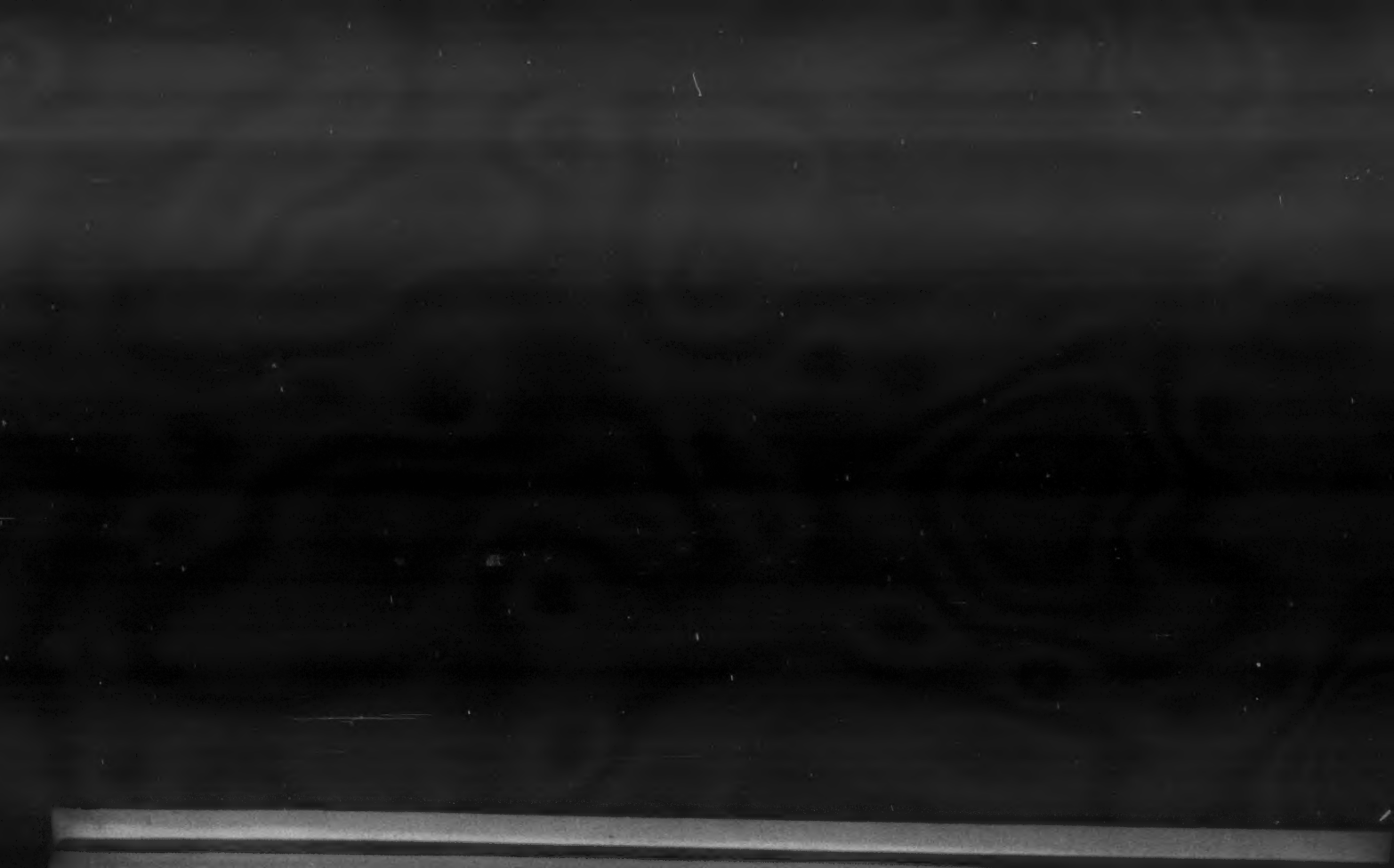
of the test gives, in figures, for all the meters tried, the same information that is conveyed by the Graphic Representation, together with further data relative to the meters tested, such as cost, space occupied, weight, etc.

The flow of water through *pipes without meters*, under all the conditions of these tests, was determined, and is recorded, and has been used in calculating the diminution of flow entailed by the use of the various meters.

SPECIAL EXAMINATION.

After the conclusion of the second accuracy test, the various meters were separately opened, their action studied and their condition examined, after which photographs were made showing the exteriors of the meters, and also all broken or worn portions of the interiors.

In discussing individual meters in the report, the operation of each is fully described.



1887

RECORD OF WATER METER

Date of Exp't.	Meter Used.	Source of Supply.	Gauge. On Main.	Gauge. Inlet Work's.	Gauge. Outlet. Work's.	Gauge. Outlet. At Rest.	H'd Lost [friction]. Inlet Pipe	H'd Lost [friction]. Meter	H'd Lost [friction]. Outlet Pipe.	H't Outlet above Meter.	Diameter. Inlet Pipe.	Diameter. Outlet Pipe.	Diameter. Orifice.	Duration of Trial h.	Duration of Trial m.
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	ft.	in.	in.	in.		
May 3	No. 45073	City Pipe.	46	13	3	0	33	10	3	0	3/4	3/4	3/4		3 3 3 3 3 1
											do.	do.	do.		3 3 3 3
May 3			46	20	12	2½	26	8	9½	7½	do.	do.	do.		4 4 4 4 4 2165
May 3			46	25	18	8½	21	7	9½	22	do.	do.	do.		4 4 4 4 4 4398
May 3			46	30	24½	14	16	5½	10½	36	do.	do.	do.		5 5 5 5 5 2287
May 3			46	36	32	21	10	4	11	51	do.	do.	do.		6 6 6 3475
May 5			46	21	12½	0	25	8½	12½	0	¾	¾	½		4 4 4 4 4 2577
July			46	25	17	2½	21	8	14½	7½	do.	do.	do.		4 4 4 14 =14-45
July 7			46	29	23	8½	17	6	14½	22	do.	do.	do.		5 5 5 16 =16-28
July 8			46	32	29	14	14	3	15	36	do.	do.	do.		6 6 0 18 =18-97
July 8			46	36	34	21	10	2	13	51	do.	do.	do.		7 7 2 23 =23-27
May 5			46	41	35	0	5	3	38	0	¾	¾	¼		9 10 9 10 4935 10
July 7			46	41	39	2½	5	2	36½	7½	do.	do.	do.		10 10 10 32 =32-73

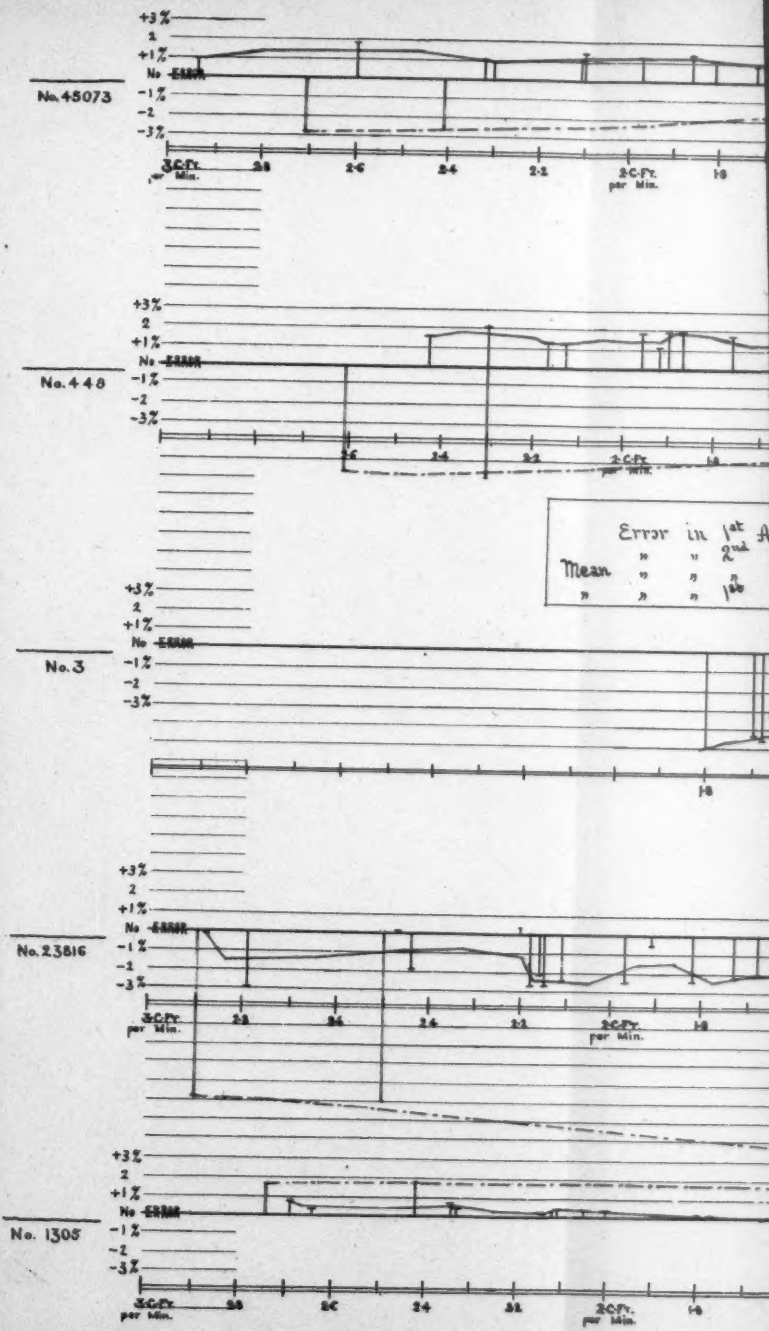
F WATER METER TEST. BOSTO

t [friction].		H't Outlet above Meter.	Diameter.			Duration of Trial.			Meter Reading.			Temperature of Water.	T Me
eter	Outlet Pipe.		Inlet Pipe.	Outlet Pipe.	Orifice.	h.	m.	s.	Begin.	End.	Quant.		By Scale.
lbs.	lbs.	ft.	in.	in.	in.				C.Ft.	C.Ft.	C.Ft.	°	C.Ft.
10	3	0	3/4	3/4	3/4		3	47	18.	28.10	101.2	50	100.
							3	47		38.20			1.002
							3	48		48.30			
							3	48		58.45			
							3	49		68.60			
			do.	do.	do.		3	46		78.75			
							3	46		88.85			
							3	46		98.95			
							3	49		109.05			
										119.10			
8	9½	7½	do.	do.	do.		4	24	120.	130.25	50.35	50	50
							4	19		140.40			12
							4	18		150.55			50.19
							4	19		160.70			1.002
							4	19		170.85			
7	9½	22	do.	do.	do.		4	51	175.	185.30	509	50	50
							4	47		195.45			18
							4	47		205.60			50.28
							4	47		215.70			1.002
							4	47		225.90			
5½	10½	36	do.	do.	do.		5	41	227.	237.50	31.	50	50
							5	32		247.60			18
							5	32		257.80			50.28
							5	33		268.			1.002
							5	34		278			
4	11	51	do.	do.	do.		6	57	281.	291.45	31.	50	50
										301.60			20
							6	57		311.80			50.32
							6	57		321.95			1.002
										332			
3½	12½	0	¾	¾	½		4	23	333.	343.10	506	50	50
							4	20		353.20			1.002
							4	18		363.40			
							4	23		373.50			
							4	22		383.60			
9	14½	7½	do.	do.	do.		4	55	475.	485.90	308	75	30
							4	44		495.60			15
							4	48		505.80			30.20
							14	27					1.004
							=14.45						
6	14½	22	do.	do.	do.		5	27	540.	550.40	308	75	30
							5	30		560.40			15
							5	20		570.80			30.24
							16	17					1.004
							=16.28						
3	15	36	do.	do.	do.		6	20	653.60	664.	309	74	30
							6	8		674.10			15
							6	0		684.50			30.22
							18	28					1.004
							=18.47						
2	13	51	do.	do.	do.		7	57	715.75	726.25	308.5	74.	30
							7	37		736.40			20
							7	40		746.60			30.32
							28	16					1.004
							=23.37						
3	38	0	¾	¾	¼		9	57	386.	396.20	506	50	50
							10	0		406.30			1.002
							9	59		416.50			
							10	0		426.50			
							10	1		436.60			
2	36½	7½	do.	do.	do.		10	59	505.30	515.10	306.5	75	30
							10	53		525.30			30
							10	52		535.45			30.13
							32	44					1.004
							=32.73						

PLATE 2.

BOSTON WATER BOARD.

	Temperature of Water.	Tank Measure. By Scale.	Tank Measure. Correct'd for Temp.	Time needed to pass 10 C.F. Actual, Min.	Time needed to pass 10 C.F. Increase due to Meter. %	Flow per minute. C. Ft.	Flow per minute. Decrease due to Meter. %	Ratio, Meter to Tank.	Error of Meter. + %	Error of Meter. − %	Remarks.
	°	C.Ft.	C.Ft.								
1.2	50	100. / 1.0021	100.21	341. / 100.21 / 3.4		100.21 / 34.1 / 2.94		101.2 / 100.21 / 1.0099	0.99		Free disch. into Tank
35	50	50 / 12 lbs. / 50.192 / 1.0021	50.297	216.5 / 50.297 / 4.3		50.297 / 21.95 / 2.32		50.85 / 50.297 / 1.011	1.1		1st Back Press.
9	50	50 / 18 lbs. / 50.288 / 1.0021	50.394	239.8 / 50.394 / 4.76		50.394 / 23.98 / 2.1		50.9 / 50.394 / 1.01	1.		2nd B. Press.
	50	50 / 18 lbs. / 50.288 / 1.0021	50.394	278.7 / 50.394 / 5.53		50.394 / 27.87 / 1.81		51. / 50.394 / 1.012	1.2		3rd B.P.
	50	50 / 20 lbs. / 50.328 / 1.0021	50.434	347.5 / 50.434 / 6.89		50.434 / 34.75 / 1.45		51. / 50.434 / 1.0112	1.12		4th B. Pr.
6	50	50 / 1.0021	50.105	217.7 / 50.105 / 4.35	25 / 4.10 / 2.1	50.105 / 21.77 / 2.3	14 / 2.44 / 5.7	50.6 / 50.105 / 1.0099	0.99		Free disch. into Tank
8	75	30 / 15 lbs. / 30.289 / 1.0043	30.338	144.5 / 30.338 / 4.76	27 / 4.49 / 6.	30.338 / 14.95 / 2.1	13 / 2.23 / 5.8	30.8 / 30.338 / 1.0152	1.52		1st Back Press.
8	75	30 / 14 lbs. / 30.224 / 1.0043	30.354	162.4 / 30.354 / 5.36	35 / 5.91 / 7.	30.354 / 16.23 / 1.86	14 / 2.39 / 7.	30.8 / 30.154 / 1.0147	1.47		2nd B.Pr.
9	74	30 / 14 lbs. / 30.224 / 1.0042	30.351	184.7 / 30.351 / 6.09	31 / 6.78 / 5.4	30.351 / 18.47 / 1.64	9 / 1.73 / 5.2	30.9 / 30.151 / 1.0181	1.81		3rd B.Pr.
35	74.	30 / 20 lbs. / 30.32 / 1.0042	30.447	232.7 / 30.447 / 7.64		30.447 / 23.27 / 1.31		30.85 / 30.447 / 1.0132	1.32		4th B.Pr.
5	50	50 / 1.0021	50.105	409.5 / 50.105 / 9.97		50.105 / 40.95 / 1.		506 / 50.105 / 1.0099	0.99		Free disch. into Tank
5	75	30 / 8½ lbs. / 30.136 / 1.0043	30.268	327.3 / 30.268 / 10.81		30.268 / 32.73 / .92		30.65 / 30.268 / 1.0127	1.27		1st Back Press.


No. 45073
No. 448
No. 3
No. 23816
No. 1305
+3%
2
+1%
No Error
-1%
-2
-3%
3 C.Fr. per Min.
2·8
2·6
2·4
2·2
2 C.Fr. per Min.
1·8
Error in 1st A
" " 2nd A
Mean " " "
" " " 1st A

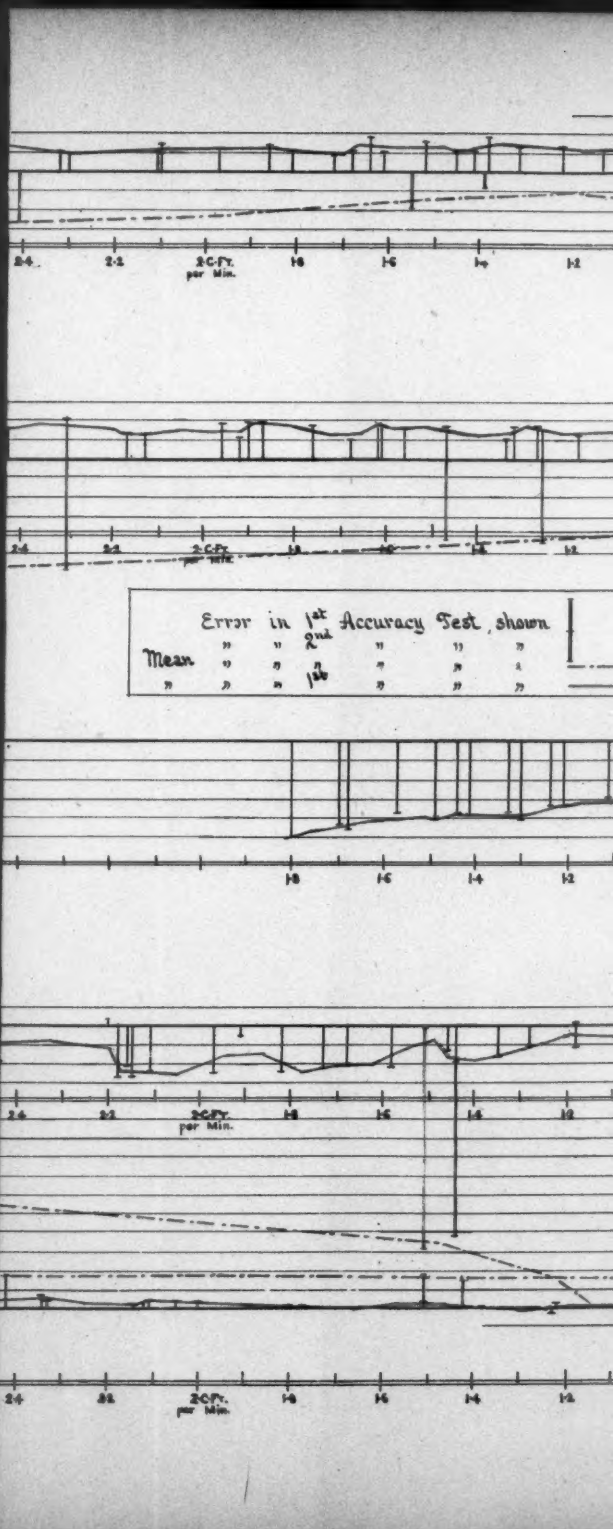
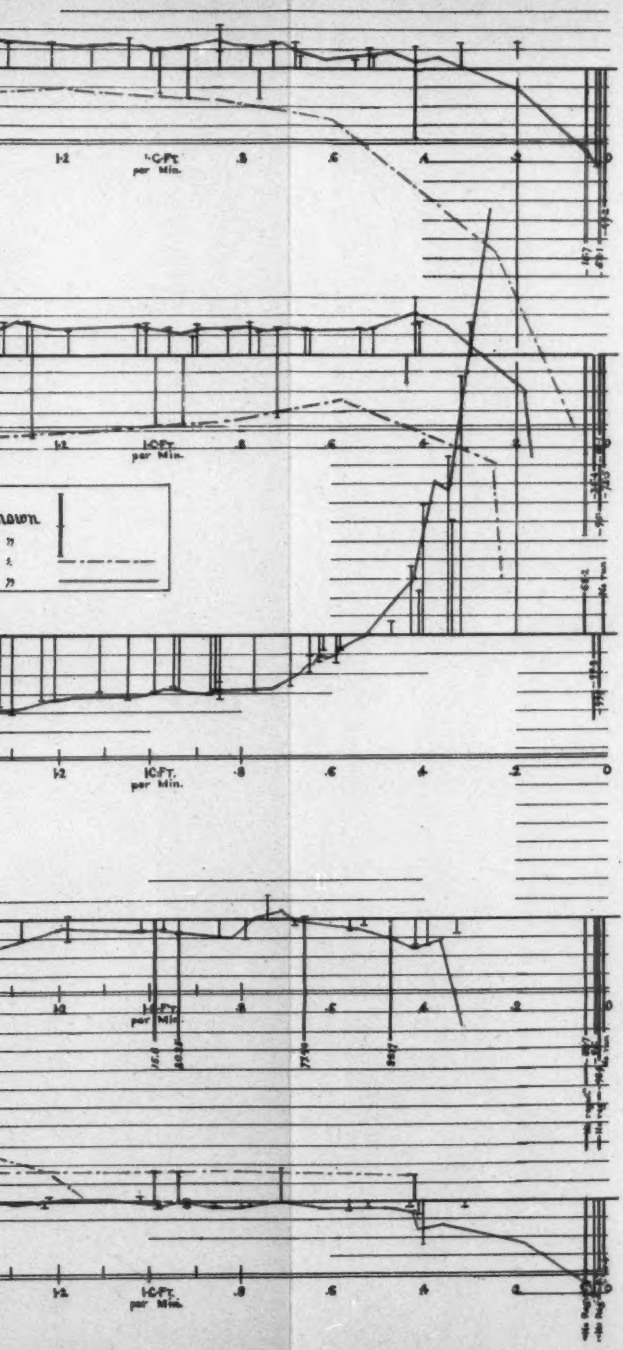

2·4
2·2
2 C.Fr. per Min.
1·8
1·6
1·4
1·2
Error in 1st 2nd Accuracy Test, shown
Mean

PLATE 3.



GRAPHICAL SHOWING OF METER ERROR.

It was the original intention of the Testing Commission to test the meters under higher pressures after the conclusion of the experiments with the pressure obtained from the city pipes and from reservoirs of low elevation.

For this purpose the connection between the street main and the testing apparatus was to be closed, and a pump applied directly to the 6-inch pipe within the testing-room, by means of which any desired pressure could be obtained, in the same manner as in the Holly or other direct pumping systems.

But the number of meters submitted for testing was so greatly in excess of the anticipations of the Water Board as to so prolong the trials that it became necessary to restrict their scope. It was, therefore, decided not to attempt any tests under the higher pressures.

In addition to these limitations, the tests conducted by the Commission dealt only with the soft, clear water supplied to Boston, and it is not assumed that they will be of use in determining the durability or continued efficiency of meters used with water in which sand or other cutting or scouring material is suspended, or which holds in solution corrosive matter.

But it is believed that the records of these tests give data which will be of value to makers and buyers of meters in considering the utility of any proposed device for measuring water under pressure and recording such measurement.

THE TESTS AND THEIR RECORDS.

In all the operations of testing and recording great care has been observed to insure accuracy.

One or more of the members of the Testing Commission has been present, and taken part in every detail, no matter how trivial.

During the bench trials, the clocks, scales, gauges, meter registers and thermometers were in all instances independently read and separately recorded by two or more observers. These notes have been carefully compared by two persons, and entered upon the record sheets, which form a part of the report. All the calculations based upon these notes have been made by two or three computers working independently of each other, and all the entries upon the record sheets, are by the same hand, carefully compared and checked by one or two revisers. Typographical errors being absolutely avoided by photo-lithographing the record sheets, it is believed that the report of the performance of the meters in these tests is substantially correct, and that it shows the action of the meters under circumstances that are identical with those attending their actual use. No two meters in actual service are subjected to precisely the same treatment, and that of any individual meter is constantly changing. No meter, in the trials here reported, has had any usage that it is not liable to encounter at any time.

DISCUSSION,

BY

A. H. HOWLAND, C. E., Boston, Mass

The paper read by Mr. Rice before The Boston Society of Civil Engineers, outlines the methods employed and results aimed at by the Commission in their most exhaustive test of water meters for the Boston Water Board. Since the reading of this paper by Mr. Rice a full report has been given to the public. It is a formidable document containing 90 pages of text, 122 sheets of tables and diagrams, and 12 pages giving reproductions of photographs of different meters and parts of meters tested, as well as the arrangement of the testing apparatus. The report does not, however, show the very interesting arrangement of supply tanks and discharge tunnels, by which different initial and back pressures were produced in the different tests applied.

Since the publication of this full report the writer has given it a good deal of study and the more he studies it the more respect he has for it. The tests were conducted in the most rational and intelligent way, and were more comprehensive and exhaustive than any tests of water meters ever before had. The Commissioners were, without exception, gentlemen without bias, with sufficient practical mechanical and hydraulic experience to know what it was essential and necessary for a good meter to be, and their tests were planned and carried out in such a manner as to best ascertain the merits of the different meters in all of the numerous conditions to which they would be liable to be subjected under ordinary use, and, at the same time that they made and reported all these tests, they maintained the most impartial position, making no comparisons whatsoever between one meter and another, but they simply took each meter by itself, subjected it to the tests and examinations and reported what they found. They recognized that their duties were to test *types of meters*, rather than *individual machines* which might display local defects of workmanship or material, and when such defects were found the Commissioners, rightly, corrected them and then allowed the machines to continue in the test; thus not damning a type of meter because some careless inspector, or workman failed to do his duty, and thereby produced a machine that was in itself incomplete and consequently not a fair sample of the type which it was intended to represent.

Since the tests were completed and the report made public the representatives of some particular meters have taken exception to the course pursued by the Commission in repairing and making good any defects of meters, claiming that a meter, having once been entered for the test, should not be repaired, changed or altered in any way; and if it failed in any particular it should be condemned. Such criticisms show the narrow field in which the parties making them travel, and one particular case, which has come to the

writer's knowledge, is almost ludicrous. One meter that was entered suffered some slight accident during the First Accuracy Test, and the Commissioners, upon examination, found a defective casting which had been overlooked by the inspector, replaced it, put the meter again into the test and it survived the entire remaining series of tests without further accident of any kind. The representative of this particular meter has publicly objected to the comparison of this meter with other meters that broke down, in some minor particular, and were repaired by the Commission during the Durability Test. All the repairs of the particular meters to which they have called attention were nothing but the repairs of imperfect or unsuitable parts, and it appears to the writer to be a very weak position, to object to the remedying of local defects during one series of tests and accepting the benefit of them in another, for if the particular meter referred to had not been repaired during the First Accuracy Test it could never have even entered the Durability Test. I think no fair minded man will do other than approve of the course of the Commission in this particular.

The different tests of the Commission appear to have been well planned in all particulars excepting, possibly, one ; meters attached to an ordinary house, or manufactory are subject to different pressures, both initial and back, and to different velocities of flow as larger or smaller fixtures in the distributing pipe system of the premises are opened. The Commission provided facilities to test each meter under many of these varied conditions, but, in testing, they tested each meter under one particular condition, completed it, then took another condition, completed that, and so on ; making the test under each condition complete in itself and not merging one test into another, whereas a meter connected, say, with a four-story apartment house is probably for a series of hours never entirely at rest, but water is flowing through it at high velocity, then at other times, at a velocity so slight as to hardly move the meter, and then at a different velocity and so on, without any regularity or uniformity of the service ; if, therefore, the Commission had arranged an apparatus by which these different conditions could, alternately, be brought to bear upon the meter and all without stopping, readjusting and again setting the meter, for a series of hours, and then have compared the weight of water actually passed with that indicated, I think it possible that some different reports in relation to some of the meters would have been made. Such a test would have taken additional time and expense, and perhaps the Commission thought of it but did not have the time and opportunity to carry it out.

Mr. Rice, in his paper, gives it upon the best authority "that the perfect meter has not yet been found," and then leads us to infer, by his following remarks, that we should not expect a perfect meter and that we should not desire a standard of measure of greater value than the commodity dealt in, and states that a five per cent. error would cost but two dollars and a quarter a year, basing his statement upon an average consumption of thirty thousand cubic feet of water worth forty-five dollars at the rate of fifteen cents per hundred cubic feet, which is the price paid for water in Boston, and, the quantity

referred to, the average yearly duty of three-quarter inch meters in the city of Boston. Now is not this two dollars and a quarter worth saving and what does it represent? All business is for the purpose of deriving revenue, in the shape of per cent, from capital invested, and in water works the water delivered is the commodity for which revenue is paid, the cost of supplying this is sometimes very great, and with a 5 per cent loss on each customer the per cent of revenue on cost is greatly reduced. What business man having thirty-five thousand customers, as the city of Boston has, can afford to give them 5 per cent of their entire goods each year at a cost of $2.25 each, or $78,750.00, which is 4 per cent annual interest on $1, 968,750.00, a sum twice as large as is necessary to meter all services? Is it not prudence, as well as business sagacity, to save as much as possible of this? The city of Boston is able as most cities in this country are at the present time, to borrow money at 4 per cent and this $2.25 or 5 per cent of loss which may be thrown away each year for each customer represents 4 per cent interest on $56.25. Therefore if you can buy a meter that will save you 5 per cent more than another meter will, you can afford to pay $56 25 more for the one than for the other. If one meter will save you 3 per cent over the other, it is worth $33.75 more and one per cent of saving is worth $11.25. On sheet 118 of the report of the testing Commission are given the average errors of the twenty-four meters tested on the First Accuracy Test, and the average errors of the sixteen meters that survived the Durability Test and were tested on the Second Accuracy Test. This table gives net prices for three-quarter inch meters of the different makes, as far as the same could be ascertained by the Commission. Of the sixteen meters that went through the test there were two whose prices are not given by the Commission but which the writer has taken pains to obtain. Now, in order to compare the relative values of these sixteen meters, according to their average accuracy as shown by the tables given by the Commission, I have taken as a basis the highest priced meter of the sixteen, and supposing that this meter is worth its money, I find that it would not pay to use one of the other fifteen meters unless the makers would make you a present of $338.50 with each meter, which you could put on interest to earn you 4 per cent to make up the value of the water which would be passed by the meter and not measured. This may appear ridiculous to some but it is strict business and the Superintendents and Engineers of this country are getting to recognize the fact that their works must be completed, maintained and operated on strict business principles, if at all. The days of "free water" and general taxes to pay the deficiency having gone by.

For the sake of contrasting relative values I have taken again that meter which is advertised as having the largest number in use of any in this country, and on the supposition that it is worth the price charged for it, I find that some other meters are worth a good deal more, as high in one instance as $17.87 more, while there are a good many that are worth considerably less. Among meters that are in use to a greater or less extent and are before the public to day I find values, relatively to the one we have taken for the present as a standard, to be $20.25, $12.375, $22.75 and so on less than the other, while there is one

meter on the list that has enjoyed, in the past, a fair reputation, that you could not afford to use, as compared with our present assumed standard, unless you could get it for nothing and have a present of $96.25 with each meter. These relative values are based entirely upon relative degrees of accuracy and have nothing whatsoever to do with capacities of meters, which should have a bearing upon prices, but should have no other than a direct relation. For instance, a meter of a given size that will pass twice as much water, in a given time under the same pressure, as another meter, and with the same degree of accuracy, is worth twice as much as the other. I find great differences in the capacities of meters under different pressures, i. e. a meter that may have a large capacity under the maximum pressure has been found to have a very small capacity under the minimum pressure, and from this we are forced to conclude there are some defects in the meter, that it is not a positive meter or else the relation of capacity to pressure would be more uniform for the different tests.

Of the sixteen meters that went through all of the tests I find there were 247 different tests for capacities made under different effective pressures, with full sized openings of discharge. Each one of the tests given by the Commission was the average of either five or three, or the 247 capacity tests for full openings are the results of over one thousand separate tests. Of these sixteen meters I find the minimum capacity to be represented by .80 of a cubic foot per minute, while the maximum capacity is 2.94 per minute, this without regard to pressure; but in comparing the capacities of these sixteen meters according to pressure I find, that, among the low pressures one meter has .82 capacity per minute while another meter under the same pressure has a capacity of 1.73 cubic feet. Again, with a little higher pressure I find a minimum capacity of 1.16 against 2.60 cubic feet per minute, and among the highest pressures I find a minimum capacity of 1.88 against a maximum capacity under the same pressure of 2.51. All of these things have their relative weight in determining which meter to use.

The ideal meter of course, is that meter which will pass the greatest amount of water in a given time with the least error, and to determine which particular meter will do this I would commend you all to a careful study of the numerous tables and plates given in the report. As a matter of interest I have attempted to classify the twenty-four meters tested and compare the results of the tests of one class with another. I find four principal classes, each of which, with one exception, is subdivided into two or more minor divisions. Taking them in the order of greatest numbers I find the Horizontal Piston Meters had nine representatives, seven of which were Double Piston Meters and two Single Piston. The Rotary Meters had seven representatives, of which two might be called double meters, five single meters, and these five single meters could be again sub-divided into Revolving and Rotating Meters, the distinction being made between those which revolve on a fixed axis, and those which do not revolve on a fixed axis, but whose axes revolve around the center of the case in which the disk is placed. The next largest class were represented by the Vertical Piston Meters, of which there were six entries,

four of which had horizontal auxiliary valves, and two of which had vertical valves; the last class, the Diaphragm, had but two representatives.

As it is not the object of this paper to describe any particular meter and show its defects or advantages over its neighbor, no comparison between meters, except as a class, will be made, and as there are so many meters in each class, and as the advantages of one may be pulled down by the great disadvantages of another in the same class it may be not either for or against a meter to be in a particular class, and no one can draw a direct comparison between any two individual meters. I see no harm in giving the classification which I make of these twenty-four meters.

The Horizontal Double Piston Meters are the "Union Duplex," "Ball & Fitts," "Terry," "Desper," "Equitable," "Worthington Improved" and the original "Worthington," as made by the city of Boston and designated as the "B. W. W." Horizontal Single Piston Meters are the "Balance Valve and the Standard." The Single Rotary Meters are the "Crown," "Johnson," and and "Tuerk," "Empire" and "Hersey," of which the first three have revolving disks, the Crown having a rotary as well as a revolving motion; while the last two have a rotary motion but do not revolve around their own axis. Of the Double Rotary Meters there are two, the "Shedd" and "Union Rotary." The next class or Vertical Piston Meters have the "Star No. 8," "Star No. 9," "Hood" and "Frost" with horizontal auxiliary valves, while the "Eagle" and "Tremont" have vertical auxiliary valves, and the last class or "Diaphragms" are the "Spooner" and "Thompson." Before giving the different ranks of these different classes I would like to explain the principal technical reasons of classification of some of these meters. Among the double horizontal piston meters, "The Union Duplex," "Worthington Improved" and "B. W. W." are substantially the same meter with different proportions and arrangements of registering parts, while the "Ball & Fitts" is a form which I think was originally intended to do the same work as, but without infringing on, the "Worthington." The "Terry" is a similar meter to the "Ball & Fitts," with its ports enlarged and re-arranged so as to give, if possible, a greater capacity with less expense. The "Desper" and "Equitable" meters have their two pistons at right angles instead of parallel with each other, as in the other Horizontal Double Piston Meters. The "Balance Valve" and "Standard" meters are very similar in appearance, the principal differences being in the form and method of moving the auxiliary valves and recording devices. Of the three Single Revolving Meters there is but little resemblance between any two of them. The "Crown" revolving once around its own axis for eight revolutions of its axis around the center of the case; while the "Johnson" revolves around a fixed vertical axis, and the "Tuerk" revolves around a fixed horizontal axis. Still, they are all Revolving Meters and must depend, for their accuracy, upon their perfection of workmanship and material, and the freedom from solid particles of matter in the water. Of the two Single Rotating Meters the "Empire" and "Hersey;" the "Empire" is caused to rotate around the center of the case by a fixed wing attached to one side of the case and working in a suitable opening in the disk of the meter; while the "Hersey" has a series of

projections on the outside of its disk, which engage in an equal number of recesses on the inner side of the case, the diameters are such that the disk cannot revolve inside of the case. The Double Rotary Meters, the "Shedd" and "Union" were intended to work in the same positions, i. e. with their axes vertical; in the "Shedd" meter the elliptical disks are channeled on their faces to make gears of them so that the relative position of the two is maintained for each revolution, while in the "Union Rotary" the main disks are smooth on their outer surfaces and their positions are maintained by elliptical gears placed on one end of the disks, which particular meter makes the tightest fits and is therefore, the more nearly accurate, a careful study of the reports in detail will determine, but the writer knows of no reason why one meter could not have been tested in a vertical position as well as the other, and thinks that the Commission made a possible error in judgment in not testing these two meters under the same circumstances as regards position. Of the Single Vertical Piston Meters having Horizontal Auxiliary valves there was but slight if any difference among them, except in the proportions of different parts and the quality of material and workmanship, while the "Eagle" and "Tremont," the other two Vertical Piston Meters having Vertical Auxiliaries were almost identical with each other. The two diaphragms, the "Spooner" and "Thompson," differ from each other materially except in the controlling and recording device.

The principal object of the above general description is merely to give the writer's reasons for these eight different sub-divisions or classes. The Double Revolving Meters ranked *first* in the First Accuracy Test, while they dropped to *fourth* position in the seven classes that survived the Durability Test, thus showing the effect of continued wear on this class of meters. The Single Vertical Pistons with Horizontal Auxiliaries, ranked *second* in the First Accuracy Test, but moved to *first* position in the second, thus showing that continued wear had little effect upon them, except to put them in a little better working condition, and to bring all parts to a more perfect working surface. The Single Revolving Rotary Meters ranked *third* in the First Accuracy Test and *second* in the second, although this advance might not have taken place if two out of three meters had not given out during the Durability Test, as the one meter which went through both tests increased its average error more than 50 per cent. during the Durability Test. The large class of Double Horizontal Piston Meters ranked *fourth* in the First Accuracy Test and moved to *third* position in the second, only one of these meters failing to pass through both tests. The Single Rotary Meters ranked *fifth* in the First Test and *sixth* in the second, showing the same results as all the other rotary meters, i. e., the error increased as the wear continued. The Diaphragm Meters ranked *sixth* in the First Accuracy Test, but did not survive the Durability Test to appear in the Second Accuracy Test. The Single Piston Horizontal Meters ranked *seventh* in the First Accuracy Test and *fifth* in the second, although one of them dropped out during the Durability Test, and the one that remained in increased its error nearly 60 per cent. The Single Vertical Piston Meters, with

vertical auxiliaries, ranked *eighth* in the First Accuracy Test and *seventh* in the second, and would probably have ranked lower in the second if there had been any other lower place for them to have reached, as their deterioration under the Durability Test was greater than any other class and almost greater than any other single meter. From this statement it will be seen that the Piston Meters increased their efficiency by use, while the Rotaries decreased, this as a class, as above noted, although there were individual exceptions.

As regards capacities the Double Rotaries ranked *first* in both tests. The Single Revolving Rotaries ranked *second* in the first and *third* in the second test, while the Vertical Pistons, with horizontal auxiliaries, ranked *third* in the first test and *fifth* in the second, this decreased ranking in both cases being due to the dropping out of one entire class of meters in one case and one out of three of the meters in the other class. The Revolving Rotary Meters ranked *fourth* in the first test and *second* in the second, while the diaphragms ranked *fifth* in the first test and dropped out entirely in the second. The Double Horizontal Piston Meters ranked *sixth* in both tests, while the Single Piston Horizontal, ranked *seventh* in the first and *fourth* in the second, and the Vertical Pistons with Vertical Auxiliaries ranked last in each class.

As the report of the Testing Commission has furnished the data from which these cold facts have been deducted the value of said report and its completeness can be well judged. These and many other things, perhaps of more importance than those mentioned, are contained in this report, and closing with the sentiments with which I opened, i. e., that the test and report are the most complete and practical of any ever made regarding the quality of meters; I would commend its careful study to all interested in this subject, and, in studying it, be sure that you study it as a whole, rather than take any particular test of any particular meter under a particular condition. Take it as a whole and form your opinions accordingly.

DISCUSSION

BY

J. C. Whitney, Superintendent Meter Department, Newton, Mass.

It is with reluctance that the request to review the report of the Boston Meter Testing Commission is complied with; the high reputation of the mechanical experts composing the board rendering one averse to criticising even slightly any of the methods used.

A brief paper will, however, bring before the Association the general subject of meter tests, and the discussion ensuing must bring out facts which will be of benefit to all meter users.

No attempt will be made to review the many excellent methods employed or the conclusions arrived at by the Commission, the few points touched upon being only those where a question arises as to whether the methods used by them were the best that could have been employed.

The aim of the Commission seems to have been to reproduce as far as was

possible in a bench test, the conditions under which a meter was required to work in actual service.

This idea was fully carried out in the first accuracy test, the meters being run on streams varying from 1-50 of an inch, to full capacity, with various initial heads and with back pressure varying from free discharge to as many pounds as they would be required to sustain in actual use.

These forty-one experiments include all the essential tests and some others, which, while not essential are interesting as showing the action of meters under certain conditions.

The apparatus used by the Commission was complete in every detail, far superior to any heretofore employed and rendered possible certain tests which could not well be carried out with the ordinary meter testing plant.

After the first accuracy test a certain quantity of water was run through the meters followed by the second test for accuracy intended to show, by comparison with the first, the effects of wear.

There were but ten experiments in the second series as against forty-one in the first. A more satisfactory basis for comparison could have been had by reducing somewhat the number of trials in the first test and by making the second accuracy test a duplicate of the first.

Bench tests intended to produce in a short space of time the effects of long continued wear in actual service are at best an unsatisfactory substitute for results obtained in practical use and in the Boston test the quantity of water passed was much too small to show adequately either the wear of the valves and pistons or the comparative durability of the various styles of intermediate gearing used in different patterns of rotary meters.

Possibly had the durability test been carried farther a less number of meters would have passed the trial successfully and perhaps their relative standing would have been changed somewhat.

Exceptions might also be taken to the manner in which the water was run through the meters; a continuous flow at their full capacity, being very seldom required of them in actual service, and the test in this particular hardly justifies the statement of the Commission, that the trials were made under conditions identical with those attending actual use.

The Commission concludes that piston meters should not be used where the pressure exceeds fifty pounds on account of the damage which the rubber bunters may receive from the blows of the plungers. It is doubtful if the majority using this class of meters will concur in this conclusion. At least one case can be cited where, with a maximum pressure of ninety-five pounds and an average of sixty pounds, three hundred piston meters have been in use for nine years without the least trouble from this cause.

The care exercised both in making the tests and tabulating the same, causes the accuracy of the published record to be accepted without question.

In conclusion it may be said that it is doubtful if any test will settle for a long space of time the question what meters are the best. The weak points of the old kinds are being constantly strengthened and new meters being brought out, each of which, (at least in the inventor's opinion) is the best in the world, but all requiring a trial to prove their worth or worthlessness.

DISCUSSION

BY

J. A. Tilden, C. E., South Boston, Mass.

While appreciating fully the valuable work of the Boston Water Meter Testing Commission as the first compilation and available record of exhaustive bench tests of water meters, I feel inclined to submit the question whether a bench test, however complete, is all that is wanted to enable a water department to determine what particular class or type of meter is desirable or suitable for its work. The question is not improper, as the commission was formed to determine this very thing.

Bench tests can be relied on more to prove radical defects of design and construction, than to prove or demonstrate the suitability of a device as a measuring instrument. Bench testing apparatus is an invaluable and indispensable adjunct to every water department using water meters, and many excellent ideas are to be obtained from a study of the paper in discussion, as to their arrangement and use.

Of course it is unnecessary to have anything more than the simplest appliances. An ample supply of water, convenient connections for the meter, a graduated tank, or better still a tank or the plebean but quite efficient barrel and scales, together with a drain of large capacity, is all that is needed.

Now what can be proved or disproved by such tests, the methods and results of which are before us for discussion, or by tests made with the more modest but available apparatus just mentioned? As a whole and in detail the appliances of the Boston Water Meter Testing Commission reflect the greatest credit upon the designer, and bear the mark of the careful engineer. Almost every test was applied that ingenuity could devise, which bore any relation to conditions which might occur in service, and yet the result was but an elaboration of similar but not so pretentious tests which have been and are going on in all parts of the country. It remains purely and simply a bench test. The conditions of service cannot be adequately represented in this way. The experiences of years of intermittent service cannot be crowded into a few weeks or months. The varied conditions of location, pressure, or rate cannot be condensed into one machine.

As a test of precision it is a necessity. As a test of capacity it is valuable. As a test of durability it is indicative. It seems to prove weaknesses rather than strength, but it must be borne in mind that whatever it shows, it is to be depended upon only for the conditions under which it was made.

Experience is daily showing that in the same city these conditions of service will so vary, from almost inexplicable and intangible causes, as to render even a service test in one part, of little value as indicating what a meter will do in another part. What then can be expected from a bench test which at the very best is an artificial, not a natural test. It will bring out many defects and inherent errors of design. It will show the weakness of a part, either due to flaws in the material or to bad proportioning. In short, it serves as the basis of judgment of the whole machine preliminary to the intimate acquaintance formed by use.

What is left to be desired—USE. The test of service is the crucial test—the bench supplementary. The bench for example, may prove that the shell or body of a meter is strong enough to stand a pressure of 40 lbs., but does it prove it will stand 80 lbs. or the unknown pressure due to water-hammer.

The bench may show that a meter can perform a large duty under a constant flow, but does it show that it will do the same under an intermittent flow? A test in clear water will show favorable results, while *use* in water containing a large amount of sediment will result differently.

A meter is so peculiarly constructed that it will run quietly on the bench, and perhaps render the house uninhabitable in which it is afterward placed by pounding, clicking, groaning, hammering and other characteristic noises.

An artificial test is not altogether reliable for the purposes of comparison. Who would think of forming an opinion as to the comparative merit of equal grades of Waltham and Elgin watches by the record of a single one of each? The bench may get hold of a superior or inferior sample. It may give a test better than the average, or not so good as the average. We may have two watches of the same grade made by the same workmen throughout the various processes, and yet there is a choice, one keeps excellent time and the other not quite as good.

Two locomotives may be turned out of the same shops and made by the same men, yet the engineers have to get acquainted with the peculiarities of their machines, as they would with the characteristics of their favorite horse.

How then should a meter be selected? First by the bench, second by actual service, third by the bench. All these tests should be made in the city or town where the meter is to be used.

The first bench test should be used for determining which are radically defective in principle, and for ascertaining the accuracy of those which are to go on a service test.

The test of actual use should comprise a number of meters widely located under every possible condition of service. High pressure and low, large flow and small, continuous and intermittent work, in short every variety attainable.

Then comes the bench again to see how far the meter has deviated from the original record.

The result of these tests then should be referred to that particular qualification of an ideal meter which is uppermost in the investigator's mind.

This is the secret of the variance of opinion as to relative merit, one will refer the result of his investigations to accuracy, another to permanency and durability, another to first cost or cost of maintenance, another to capacity, another to convenience, while others look to general practical efficiency.

The water works fraternity will fully appreciate the great work of Mr. Rice and his brother commissioners, as it has already taken the place as authority on scientific meter testing.

But in saying that something more is wanted I believe I am voicing the sentiment of those intimately connected with the management of water works.

WHAT IS THE SAFE RATIO OF PUMPING CAPACITY TO MAXIMUM CONSUMPTION?

BY

WILLIAM B. SHERMAN, C. E., Providence, R. I.

In the proper selection of the source of supply for Water Works the first question to be determined is its quality—its fitness for domestic purposes. This settled satisfactorily, the next most important factor is the quantity available,—is it sufficient for the works in view during the season of greatest drought? To satisfy this query, the probable growth of the district in population is estimated for a term of years, twenty-five, fifty or even more, as the case may be,—an ample consumption per capita is fixed upon, and the minimum flow ascertained. Upon these three data the question of quantity is decided.

These two main desiderata, quality and quantity, apply with equal force to both gravity works, and works where pumping is indispensable. In pumpage works the water is distributed by several systems, from a reservoir located on a height sufficiently elevated to give adequate pressure at all points, from a tank similarly located, from a stand pipe, or by direct pumping into the mains. Some works embrace a combination of two or more of these systems. In determining the question of quantity to be pumped for distribution, and consequently the capacity of the pumping machinery, it is not necessary to make provision for such an extended period, as is used in the selection of the source of supply.

The distribution system may be increased from time to time with great facility, so that at the outset it is rarely found that the several elements of a carefully studied system of water works are perfectly harmonious. In providing pumping machinery it can be easily arranged so that additions may be made when required, without interference with the original plan.

We now come to the main topic to be discussed in this paper. What pumping capacity shall be provided to meet all demands?

Mr. N. Henry Crafts, in his report to the Town of Watertown, Mass., in 1876, says: "It is *desirable* in every system of public water supply to secure immunity from accidents, from faulty construction, and from carelessness in management; in a word, we aim to secure *safety*. Now, while all admit that safety is of the utmost importance, and engineers, commissioners, and all who have charge of the construction of water works systems, endeavor to conform their works to its requirements, it must be admitted by everyone that *absolute safety*, or, as it may be expressed, *infallibility* in every particular in works of human construction is not attainable. The most we can do is to approximate and reach what may be called *safety in a reasonable degree*. In practice, we have frequently to weigh small risks against very large outlays of money, and in determining the danger of any risk, we are governed by a careful study of probabilities, and not frightened by visions of remote possibilities. Pre-

cisely what constitutes *safety in a reasonable degree* is a question upon which both engineers and practical men differ widely, and economic considerations have great weight in most cases. There may be alternative safeguards, so nicely balanced as regards efficiency, that relative cost becomes the determining element. That engineers differ, when they come to adjust the line of *reasonable safety*, is especially noticeable where there is a wide disparity in pecuniary means. An engineer who has millions at his command, is not likely to trouble himself much about adjusting this line very nicely, so as to harmonize with true economy, and it frequently happens that precedents and standards are thus established, not justified by either considerations of reasonable safety or judicious economy. * * * "

"Now, when we come to study pumping works under the reservoir system, we shall find, probably, as wide a diversity in regard to just where the line of *reasonable safety* lies. One engineer will insist that the reservoir should hold ten days' supply, and another twenty, and both may be obliged to lower their standards, on account of excessive cost. * * * * "

"There is, however, a pretty well established standard of *reasonable safety* as regards the general arrangement of pumping works on the reservoir plan.

"The common practice is to estimate liberally what the daily requirements will be at the end of ten or fifteen years, and to provide a single engine capable of doing the work at that time by working twelve hours per day. Thus, if the present requirements of a town were 300,000 gallons per day, and the probable rate of increase were fifty per cent. decennially, an engine would usually be provided capable of pumping 500,000 gallons in twelve hours, or what is usually styled a 'million gallon engine.'"

It would naturally appear that pumping capacity is dependent to a greater or lesser degree upon the system of distribution. While it is not the purpose of this paper to discuss the merits of the several systems, it may be stated, that if a reservoir system is practicable, and is carried out, a smaller pumping capacity could safely be put in, than if pumping direct, or by means of a stand pipe of small dimensions. In many new works, of below the medium size, and especially on the direct pumping system, a certain number of fire streams, to a stated height, is fixed upon as the measure of what the maximum demand shall be; and if the works are arranged to perform this set duty satisfactorily, the supply is considered ample for all daily requirements. In connection with this subject, it will be interesting to ascertain what amount of water is actually used at fires.

The published annual reports of water works contain but little data on this subject.

The most destructive fire which ever occurred in the city of Providence, R. I., was on September 27, 1877, when $362,000 worth of property was destroyed. Twenty-five streams were playing at one time for a number of hours, (17 from hydrants, 8 from steamers,) using while in service 268,000 gallons per hour. In the same city, on February 15th and 16th of the present year, occurred the "Aldrich House" fire, at which time several large buildings were destroyed. The total quantity used is estimated at "2,000,000 gallons,—maximum per hour may have reached 292,000,—probably could not have been

less than 241,000." Mr. M. L. Holman, Water Commissioner of St. Louis, Mo., in a paper printed in the American Water Works Association transactions, describing the burning of the Collier Lead and Oil Works in that city in 1881, gives as the aggregate quantity of water thrown by the ten fire engines, 3,375 gallons per minute, which is equal to 202,500 gallons per hour, or at the rate of 4,860,000 gallons per 24 hours. The amount paid by insurance companies on the Lead works and adjacent property was about $81,000.

From reports of Norfolk, Va., with population in 1880 of 58,564, the following is tabulated :

FIRE SERVICE.

	'80-'81. (12 M'ths)	'81-'82. (12 M'ths)	'82-'83. (12 M'ths)
Total amount per year, (gals.)	2,069,089	519,194	1,309,031
Average amount per fire, (gals.)	57,475	57,688	50,349
Average length of time per fire, (hours)	.92	1.03	.86
Total length of time of fire during year, (hours)	33.12	9.28	22.33
Alarms during year	36	9	26

The city of Fall River, Mass., since the establishment of its water works in 1871, has been visited with several most disastrous fires. The system of pumpage adopted here is that of stand pipe of small capacity, (42" diameter) therefore, during these conflagrations the pumps were very accurate meters of the quantity used each hour.

The table on the opposite page is taken from the fourth annual report of these works, and gives the details of six large fires.

These works possessed only one engine (five million capacity) up to about January 1st, 1876, so that this was the sole dependence at the time of the three first fires mentioned in the table. It will be noticed that the extra amount for fire in 24 hours did not exceed one and one-half million gallons in any case, the average quantity for the six fires being about 650,000 gals. per 24 hours. Mr. Rotch, Chief Engineer, in his annual report for 1876, says: "The American Print Works has 65 hydrants in all, which can be supplied from the Water Works and from the force pumps of the establishment, either independently or together, capable of throwing 129 streams, while outside within 50 feet of the buildings are four hydrants, throwing 14 streams, making a total of 69 hydrants, capable of throwing 143 streams. During the fire, December 8th, 1874, between 40 and 50 streams were thrown at one time upon the buildings; and during the fire at the American Linen Mill, June 29th, 1876, 22 streams were supplied by the Water Works. There are in Fall River 40 cotton mills, and about a dozen other large manufacturing establishments." The following is an extract from Mr. Rotch's annual report for 1887. "On the 17th of Nov. 1877, Border City Mill was burned; this was the largest and most disastrous fire that has occurred since the Water Works were established. There are three city hydrants within 175 feet of the mill, which were all in good order on the day of the fire, and at one time eleven streams were thrown from these hydrants

COMPARATIVE STATEMENT OF THE AMOUNT OF WATER PUMPED FOR THE SIX LARGEST FIRES THAT HAVE OCCURRED DURING THE FOUR YEARS THAT THE WATER WORKS HAVE BEEN IN OPERATION.

Building burned	Granite Mill.	Am. Pr. Wks.	Mass'soit Mill	Marvel, Davol & Co.	Am'c'n Linen Mill.	B. C. Mill.
Date	Sept. 19, 1874	Dec. 8, 1874	Nov. 2, 1875	Apr. 14, 1876	June 29, 1876	Nov. 17, 1877
Time of alarm	6.54 A. M.	8.02 P. M.	11.35 P.M.	12.05 A. M.	6.23 P. M.	5.57 A. M.
Gallons pumped in 24 hours	830,208	1,376,274	1,658,346	918,077	2,145,600	2,452,482
Av'ge for 24 hrs. dur'g current month	725,943	888,279	861,070	806,806	1,196,846	1,007,872
Extra amount for fire in 24 hours	104,265	487,995	797,276	111,271	948,754	1,444,610
Maximum for 1 hour during fire	96,048	160,356	135,654	118,927	201,292	182,400
Equivalent rate for 24 hours	2 305,152	3,848,544	3,255,696	2,854,248	4,831,008	4,377,600
Av'ge for corresponding hour, during current month	46,567	4,968	9,635	10,033	59,246	60,600
Extra for fire, during 1 hour	49,481	155,388	126,019	108,894	142,046	121,800
Total amount pumped for fire	104,265	487,995	797,276	111,271	948,754	3,035,475
Estimat'd value of property destroyed,	$246,909.30	$17,653.83	$140,000.00	$24,000.00	$183,000.00	$450,000.00
Maximum number of streams at one time from city hydrants	7	8	10	8	8	11
Maximum number of streams supplied by Water Works at one time	7	25	10	8	22	11

under a pressure of about 90 to 100 lbs. per square inch. The water in the stand pipe was at no time less than 240 feet above the hydrants which are about 3¾ miles distant."

In the annual report of Cincinnati W.W. for 1878 the quantity of water used for extinguishing fires for that year is given at 18,100,000 gallons.

On this subject of fire service, Mr. Crafts, in his Watertown Report before quoted, says:— "It is well known that the demands for fire purposes, on the pipes which belong to the distribution system, is very largely in excess of the ordinary demand for domestic and other uses, as the supply must be concentrated at the particular locality where the fire occurs. In the closely built sections of large cities, this fire supply is estimated at 3000 gallons per minute, and in the outskirts at 2000 gallons per minute, and the least capacity of the pipes must be equal to this demand."

The following extract is taken from Col. J. T. Fanning's work on Hydraulic Engineering on the subject of varying consumption: "In illustration we will assume a case of a suburban town requiring, say, an average daily consumption for the year, of 1,000,000 U. S. gallons of water, and compute the maximum rate of draught on the bases shown by the above named diagrams thus:

	Gallons per day.	Gallons per min.	Cubic ft. per min.
Average draught per year	1,000,000	694.4	92.8
Add 17 per ct. for max. monthly average draught making	1,170,000	812.5	108.6
Add to the last quantity 10 per cent for the max. weekly average draught making	1,270,000	881.9	117.9
Add to the last quantity 37 per cent. for the max. hourly average draught making	1,640,000	1138.9	152.3
Add to the last quantity 23 per cent. for the max. hourly average draught on Mondays making	1,870,000	1300.0	250.0

"The experience of nearly every water supply shows that the maximum draught aside from fire service, is at times more than double the average draught."

"In addition to the above, there should be an ample reserve of water for fire service, and extra conduit and distribution capacity for its delivery. There is a possibility of two or three fires being in progress at the same time, in even the smaller cities, requiring at least twelve hydrant streams, or say 300 cubic feet of water per minute for each fire."

In the annual report of Dayton, Ohio, W. W. for 1878, the Engineer says: "During fire service there has been pumped 3,408,450 gallons, against 1,904,670 gallons pumped in 1877. * * * The total time during the year that fire pressure was maintained in the pipes, was twenty-four hours and twenty-five minutes."

At the installation of any system of water works, requiring pumping, its capacity is generally much in excess of the requirements. As the use of water from the public supply becomes general, this excess is gradually reduced; until in a few years the pumps are worked every day to keep up with the demand. Arriving at this juncture, those in direct charge, Engineer and Water Board, fully alive to the necessity of duplicating the pump capacity, urgently recommend these additions in their communications to the city government.

City Councils, as commonly made up, are bodies of men representing all trades and professions, all classes of society and as many different ideas, whose responsibility ends with the year, and who cannot be brought to the bar of justice to answer for the procrastination of any official duty. As a consequence urgent appeals for appropriations are tabled for one, two and sometimes three years, the daily consumption of water increasing all the while, and consequently the ratio of pump to max. consumption becoming nearer equal.

The annual reports of Water Works, tell of the great risks from these delays and the narrow margins of escape from short supply.

The following extract is taken from the 3rd Annual Rept., City of Atlanta, Ga., * for year 1877:— "The engines have performed their work steadily and well although they have been run, for a greater portion of the time, up to their full capacity, and during the time that the broken pump was out of service, the other three performed more work than had ever been required of the four, which run them faster and at greater risk than was contemplated by the makers. We were exceedingly fortunate in being able to meet the demands for water. At certain hours of the day it was found next to impossible to maintain the domestic pressure, and the demand for additional machinery was never more severely felt. As will be seen by reference to the table of duty, the consumption during the month of August ran up to 43,000,000 gallons, or more than 1,300 000 per day.† When it is known that this consumption was supplied with three pumps and that the four were only calculated for a supply of 2,000,000 in twenty-four hours, and that for about nine hours of the twenty-four comparatively little water is taken, you will realize the speed at which it was necessary to run the machinery."

On a subsequent page of this report it is stated that the city of Atlanta contracted in June 1877 for another pump of 3,000,000 capacity and same would be ready for service the first of 1878.

In the 9th Annual Report Dayton‡ (Ohio) W. W., the engineer says: "In my last report I called your attention to the inefficiency of the old engine,' and I cite the following: 'If any accident should occur to the new engine while operating in time of fire we would be dependent on the old engines, and should the fire be of any great magnitude we would be unable to supply the demand for water.' The prediction was slightly verified during the year as follows: on the 16th day of September at 7.30 a. m. the forked connecting rod on the right back engine was discovered to be fractured, the old engine

*Pop. 1880. 37,409. Date Construction Works 1875. System Direct Pumping.
†Av. daily consumption for the year 1,112,362 galls.
‡Pop. 1880, 38,678. Date of Construction W. W. 1870. System, direct pumping.

was immediately started, and the disabled rod disconnected for repairs, and at this time the largest fire of the year occurred, at Meade & Nixon's paper mills. Fortunately the engines of the new machinery can be run independently of each other, and by running the three remaining engines in connection with the old engines, we were enabled to maintain the pressure during the continuance of the fire, which lasted three hours and ten minutes. Had the new engines been entirely disabled, it would have been impossible to have supplied one-half the amount of water required on the fire." The engineer urges the necessity of increasing the capacity of the old pumps.

In the tenth Annual Report for 1879, the Trustees call attention of the Council of Dayton to the necessity of additional pumping facilities. Yet it is not until late the following year that anything is done. The following is taken from their 11th Annual Report for 1880. "An agreement was entered into on the 4th day of October with the Holly Manufacturing Co. for a four cylinder pump to take the place of the old gang and rotary pumps, thereby increasing the capacity of the old engines." * * * * * * *

"This improvement will give us two complete sets of pumping machinery, each with a capacity of four million gallons; and also furnish an almost absolute security against any possible contingency that may arise by either becoming disabled."

The Annual Report of the city of Milwaukee for 1878 states: "The average daily consumption of water during last year (1878) was 8,890,536 gallons;* and the estimated daily pumping capacity of the present machinery is 16,000,000 gallons. The average amount of water stored in the reservoir does not exceed 18,000,000 gallons, being about two days supply, showing plainly that should one of the engines or pumps be out of service for any considerable length of time, the present consumption of water could not be supplied."

"The propriety of duplicating some important parts of the machinery, to guard against loss of time in case of breakage or accident has been suggested to the Committee on Water Works, and the work will doubtless be authorized by the Common Council."

The City Engineer Mr. Hilbert in his annual report for the year following (1879) says:— "The accompanying diagram, which gives the rate of increase of the daily consumption of water for the corresponding weeks in 1878 and 1879,† shows clearly that great risk is being incurred by the city in respect to its water supply, without any allowance for possible accidents, the present demand added to the probable increase will soon in the warmest and coldest seasons of the year be equal to or above our maximum pumping capacity, I therefore most earnestly renew my recommendation of last year that the city should proceed at once to the construction of an additional engine."

The city of Pawtucket, R. I. has taken some very narrow chances in keeping pace with the demand for water. The first engine was started Jan. 31, 1878. The project to increase the pumping capacity was defeated at a Special Town Meeting held in Feb. 1882. Six months later however in August, "the town by

*Maximum, 11,200,000.— ratio, 1: 1.39.

†Maximum daily consumption for 1879, 13,200,000.

vote sanctioned the recommendation of the board." In the 4th Annual Report for year ending February 1, 1884, the Superintendent Mr. Darling says :— "At the old station extensive repairs were rendered necessary by the breaking of a piston rod and cylinder head, caused by the corrosive action of the water on the piston rod where it passes through the plunger in the pumps. It was not entirely unexpected, as the condition of the rod was known, and replacing it with a new one already on hand was contemplated as soon as general safety would permit. Unfortunate as the accident was, the advanced state of the new station enabled it to take care of the supply while the repairs were being made. Had the accident occurred a week earlier the amount of expense would have been but a small item in comparison to the trouble and inconvenience of being without water or on short allowance. But as the new station had just arrived at the stage where a trial of its machinery could be made, the water flowed on in the even tenor of its way, and but few were aware of the trouble till it was past." A third station has just been completed for these works containing a 6,000,000 pump.* During the past season there have been times when the two pumps working at speed failed to keep the water from lowering in the reservoir. Records show that for the six months, May to October inclusive, the engine at No. 1 station run 89.51 per cent. of full time and for August run 717 hours 20 minutes out of a possible 744 hours.

In the Journal of the Association for March, 1888, there was published a table showing a maximum, minimum and average daily consumption of water and pumping capacity of the water works of 29 cities and towns for the year 1886. The average daily consumption ranges from 235,178 gallons, the lowest, to 37,000,000 gallons as the highest, and a pumping capacity from 1,200,000 gallons to 63,000,000. The ratio of pump capacity to maximum consumption varies from 1.21:1 to 8.04:1. The maximum consumption exceeds the average consumption by 130 per cent. in the extreme case, and a least variation of 12 per cent.

The cities of Des Moines, Ia., and Fall River, Mass., each on the direct pumping system, each works constructed in the same year (1871,) and each with a pumping capacity of 13,000,000 gallons, have ratios of maximum consumption to pump of 1:5.14 and 1:4.98 respectively. The first is operated by a company and the second by the city. Taunton, Mass., also pumping direct, has a ratio of 1:2 less than one-half the margin of the other two. The ratio for works on the reservoir system is shown to be from 2.5:1 to 3:1.

From the data here given regarding the amount of water required for fire service, it may be concluded that a rate of 200,000 gallons per hour is ample, and that the total quantity for the twenty-four hours will not exceed 2,000,000 gallons for this service for a single large conflagration. A system of works having a reservoir of eight or ten million capacity possesses an ample reserve to meet this fire service even with the pumps not in operation. In systems of direct pumping with no reserve the capacity of the pumps must be such as will fully meet this maximum demand.

*This gives total capacity of 12,000,000 gallons in 24 hours, in 3 sets of machinery.

A safe ratio for reservoir systems may be stated to be such that the machinery in duplicate will meet the maximum consumption in 12 hours run, so that if either be disabled the other can do the required work by running full time. For direct pumping, the maximum consumption is likely to be augmented by demand for fire purposes of say 200,000 gallons per hour, and a safe ratio would be to have machinery duplicated, of capacity sufficient for such emergencies. It was not the purpose of this paper to attempt a conclusive answer to the question which its title propounds, or to formulate a method which could be applied with mathematical precision to all cases; but to collate some data bearing on the subject, inviting criticism and discussion.

The "Engineering News" in its statistics of New England Water Works recently published, records 255 as the total number of works, of which 130 are gravity and 125 are supplied by pumping, nearly equally divided as between the two systems.

There are therefore many members of this Association capable of discussing this question from personal experience, and it is earnestly hoped that all may do so.

OBITUARY.

ALBERT F. UPTON,—General Manager Jarvis Engineering Co., Boston, Mass. Died June 8th, 1888. Age 45 years. Joined this Association April 21st, 1885.

LEWIS H. PENGILLY,—Civil Engineer, Tuxedo Park, N. Y. Died September 22nd, 1888. Age 31 years. Joined this Association June 13th, 1888.

WILLIAM C. McCLALLAN,—Contractor, Boston, Mass. Died September 15th, 1888. Age 60 years, 5 months, 29 days. Joined this Association June 16th, 1886.

Mr. McClallan has been prominently engaged in the building of Engineering Works since 1856, including Water Works at New Haven, Windsor, Chicopee, Quincy, Weymouth, Sharon, Cohasset, S. Framingham and Marblehead. He will be greatly missed by the many members of this Association who have had personal or business relations with him.

New England Water Works Association Membership Roll.

The following corrections should be made in the membership roll published in September, 1888.

George Alexander,
74 Federal Street, Boston, Mass.

W. S. Chaplin,
Professor of Engineering, Harvard University, Hammond Street, Cambridge, Mass.

E. H. Gowing,
Reading, Mass.

J. H. Decker,
Secretary, Treasurer and Manager, Winfield, Kans.

B. C. Mudge,
Barr Pumping Engine Co., 74 Federal Street, Boston, Mass.

L. A. Taylor,
Civil Engineer and Contractor, United States Hotel, Boston.